# Project Report

ETS-12

E. W. Rork

## Detections of Faint Geosynchronous Satellites at the GEODSS ETS from October 1976 to March 1977

10 June 1977

Prepared for the Department of the Air Force
under Electronic Systems Division Contract F19628-76-C-0002 by

**Lincoln Laboratory**

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the Department of the Air Force under Contract F19628-76-C-0002.





This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Raymond L. Loiselle

Raymond L. Loiselle, Lt. Col., USAF
Chief, ESD Lincoln Laboratory Project Office

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

# DETECTIONS OF FAINT GEOSYNCHRONOUS SATELLITES AT THE GEODSS ETS FROM OCTOBER 1976 TO MARCH 1977

*E. W. RORK*

*Group 94*

PROJECT REPORT ETS-12

10 JUNE 1977



LEXINGTON MASSACHUSETTS

ABSTRACT

This report presents a record of faint geosynchronous satellites detected at the GEODSS ETS from October 1976 to March 1977. The satellites reported have at one time or another been difficult or impossible to detect electro-optically because solar reflections from them were faint.

DETECTIONS OF FAINT GEOSYNCHRONOUS SATELLITES AT THE GEODSS ETS FROM OCTOBER, 1976 TO MARCH, 1977.

I. Introduction. Certain geosynchronous satellites have only occasionally been detected at the GEODSS ETS because in general, solar reflections from them are too faint. Satellites as faint as 17.9 $m_v$ have been detected at the ETS using TV-integration. The ETS has been searching for and detecting synchronous satellites on a regular basis since it began operations in September 1975, partly to discover any difficulties in detecting them electro-optically as a function of night-sky brightness, atmospheric extinction, the sun-observer-satellite angle, and physical characteristics of the satellite itself. For example, certain synchronous satellites were not detected during the summer solstice, 1976, but were detected at other times of the year.[1] At the time of a summer solstice, the high declination of the sun causes specular reflections from synchronous satellites with surfaces oriented parallel to the earths axis to be reflected southward, hence such satellites must be detected from diffuse solar reflections.[2]

The ETS now has a greater detection capability by the use of an automatic moving-target-indicating (MTI) device, and TV-integration. This report summarizes observations of a series of synchronous satellites at the ETS which have occasionally not been detectable. Since reasonable attempts were made to eliminate

telescope pointing as the reason for not detecting a satellite, the most likely reason was that it was too faint. The observations reported are part of a project now being carried out at the ETS to determine when and if, during the year, certain synchronous satellites are not detectable.

## II. Current Detection Capability.

Three methods of confirming the presence of a satellite in a field of view (FOV) are currently used at the ETS:

1. Normal TV-Rate Display. After the computer-controlled telescope has been directed to a computed satellite trajectory, the operators may first try to spot the satellite moving with respect to stars displayed on a video monitor. Using the 31-inch ETS sensor in a clear dark sky, a satellite as faint as about 16.5 visual magnitudes can be spotted in the $1^{o}$ FOV, and a satellite as faint as about 17.5 visual magnitudes can be spotted in the $0.5^{o}$ FOV. The visual magnitude figures are given for the case of no atmospheric extinction. Such detections, however, require the operators to be very alert.

2. Automatic Moving Target Indicating Device. A device has been recently installed at the ETS which provides:

    1. a video display with star images cancelled out, leaving on the display any object which moves from one resolution cell to another during a preset time interval, and

    2. an indication alarm and mark around the object on the TV monitor if it is present.

    The automatic detection sensitivity achieved is about 15.5-16.0 visual magnitudes in the $1^{o}$ FOV, and 16.3-16.9 visual magnitudes in the $0.5^{o}$ FOV. However, operators must

visually inspect the display to confirm the presence of a moving satellite, since a few false alarms may accompany a faint detection. In addition, the operators may visually detect satellites as faint as those able to be detected on the TV-rate display by examinining the processed video display of the MTI device. Faint detections are easier, because stars have been removed from the display, and a TV-integration of up to 8 video frames improves the signal-to-noise ratio produced by the image of a faint satellite.

The usefulness of the MTI device is most apparent when a large area of the sky must be searched to find a satellite. In this case, a large number of fields must be sequentially examined in a step-stare search program.

3. TV-Integration. To search for a satellite suspected of being fainter than the 17th visual magnitude, integration is used both on the TV camera and an external storage device to increase the video signal-to-noise ratio from a possible satellite image. In such an operation, it is necessary for the image of the satellite to remain in the same resolution cell of the TV sensor during the entire integration time, which is typically about 9 seconds. Since the angular diameter of a resolution cell of the current 31-inch ETS sensor is either 5 or 10 arc seconds, corresponding to the $0.5^{o}$ or $1^{o}$ FOV, respectively, and since a synchronous

satellite moves at an angular velocity of about 15 arc seconds/sec eastward with respect to the stars, it is necessary to drive the telescope close enough to the angular velocity of the satellite to keep its image in a resolution cell during the integration time. If the SNR of a satellite in the field reaches 10, it can be detected at a glance against the streaking stars on a video monitor; however, if it is only about 3, it is very hard to detect visually. In the latter case, the telescope must be moved to track at an offset from the original position and the integration process repeated to see if the faint object has moved. Frequently, this procedure must be repeated several times to confirm the presence of a faint satellite. In dark, clear skies, using the $0.5^{\circ}$ FOV of the 31-inch ETS sensor, an 18th visual magnitude object can produce a SNR = 10 after about 9 seconds of integration. Integrating beyond 9 seconds doesn't help in the present set-up because the video signal due to sky background and/or dark current becomes too prominent. Future experiments are planned in which the target of the camera tube will be cooled to reduce its dark current to permit longer integration times.

III The Satellites Observed.

A historical record of the observations made on the satellites is presented on Table 1. Figure 1 is a graphical record of the detections as a function of the day, sun declination, and lunar phase. A few brightness measurements have been reported in Table 1, primarily for the faintest detections.

We notice that:

1. 83501, 83502, 83512 were fainter around the winter solstice, 1976, (day 6356), when specular reflections would be furthest north.

2. 83546, 83547, 83550, the IDCSP satellites, were not detected near the time of the winter solstice, and were very faint at other times.

## IV. Conclusions.

Satellites were detected as faint as 17.9 $m_v$ in these observations. It is probable that some of the satellites in Table 1 were fainter than 17.9 $m_v$ when they were not detected. If it is necessary to routinely detect satellites fainter than the 18th visual magnitude, it will be necessary to improve the E-O detection process for GEODSS. This can be done by increasing telescope aperture, improving detector resoultion, increasing integration time, and improving MTI efficiency, possibly with considerable software treatment to the data. It will be difficult to accomplish this without increasing search time appreciably.

The observations reported are part of a project now being carried out at the ETS which is to detect the satellites listed in Table 1 on a regular basis if possible, up to and through the summer solstice, 1977. A record of such observations will indicate:

1. If and when the satellites become too faint for TV rate detection;
2. How faint they become; and
3. If and when they are too faint to be detected by integration at the ETS.

Such information, when correlated with the sun-observer-satellite angle and night-sky conditions, will help establish a necessary detection sensitivity threshold for the GEODSS program.

ACKNOWLEDGEMENTS

Many GEODSS ETS site personnel of M.I.T., Lincoln Laboratory and the U.S.A.F. Air Defense Command have participated in the searches for and detections of the satellites reported herein, and their work is greatly appreciated. The author thanks Dr. J. M. Sorvari for his estimations of the brightness of 83547 and 83550 on UTD 6290.

## REFERENCES


1. E.W. Rork, "Brightness Measurements Taken With The GEODSS Experimental Test System on Synchronous Satellites During the Summer Solstice, 1976," in the Proceedings of the Eighth NORAD Spacecraft Identification Conference (NORSIC-8), 2-6 August 1976 (to be published).

2. A.S. Friedman, "Determination of Specular Reflection from Cylindrical Satellites for Electro-Optical Surveillance and SOI" Project Report ETS-3, Lincoln Laboratory, M.I.T. (8 October 1976), DDC AD-A03458011.

TABLE 1. A Record of Detections of and Searches for Faint Synchronous Satellites at the GEODSS ETS from October, 1976 to March, 1977.

Legend: B: Satellite was bright enough to be readily detected.
F: Satellite was faint, and may have been hard to boresight. In general, the symbol F was used when the satellite visual magnitude was fainter than about 15.5.

The standard deviation in the brightness measurements is estimated to be 0.2 $m_v$ except where a $\sim$ sign appears, in which case it could be 0.3 or 0.4 $m_v$.

TABLE 1.a

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| 83501 | NATO 2 | 6323 | | 1 | | | |
| | | 6328 | | 1 | | | |
| | | 6329 | 2 | | X | ∿17 | |
| | | 6330 | 1 | 1 | X | 17.0 | |
| | | 6338 | | 1 | | | |
| | | 6342 | | 1 | | | |
| | | 6356 | 2 | | X | 17.1 | |
| | | 6357 | 2 | | X | ∿17 | |
| | | 6358 | 1 | | X | 17.0 | |
| | | 6363 | 1 | 3 | X | 17.1 | |
| | | 6364 | 2 | 5 | X | 16.4 | |
| | | 7007 | | 1 | X | | |
| | | 7011 | | 1 | | | |
| | | 7014 | | 1 | | | |
| | | 7025 | 1 | | | F | |
| | | 7028 | 3 | | X | F | |
| | | 7029 | | 2 | | | |
| | | 7039 | | 1 | | | |
| | | 7040 | 1 | | | 15.3 | |
| | | 7045 | 2 | | | 15.4, 16.0 | |
| | | 7048 | 1 | | | B | |
| | | 7049 | 2 | 1 | | F | |
| | | 7050 | 2 | | X | F | |
| | | 7063 | 4 | | | B | |
| | | 7067 | 1 | | | B | |
| | | 7068 | 1 | | | B | |
| | | 7069 | 1 | | | F | |
| | | 7073 | 1 | | | B | |
| | | 7074 | 1 | | X | F | |
| | | 7075 | 2 | | | B | |
| | | 7077 | 1 | | | F | |

TABLE 1.b

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7078 | 1 | | | B | |
| | | 7082 | 1 | | | F | |
| | | 7083 | 1 | | | B | |
| | | 7089 | 1 | | | F | |
| 83502 | NATO 1 | 6287 | | 1 | | | |
| | | 6294 | | 1 | | | |
| | | 6304 | | 1 | | | |
| | | 6323 | | 1 | | | |
| | | 6328 | | 2 | | | |
| | | 6329 | 1 | | X | ∿17 | |
| | | 6330 | 1 | | X | 17.0 | |
| | | 6338 | | 1 | | | |
| | | 6339 | | 2 | | | |
| | | 6349 | | 1 | | | |
| | | 6351 | | 1 | | | |
| | | 6356 | 3 | | X | 17.1 | |
| | | 6357 | 2 | | X | ∿17 | |
| | | 6358 | 1 | | X | 17.0 | |
| | | 6363 | 1 | 3 | X | 17.1 | |
| | | 6364 | 1 | 2 | X | 17.4 | |
| | | 7011 | | 1 | | | |
| | | 7012 | | 1 | | | |
| | | 7014 | | 1 | | | |
| | | 7020 | | 1 | X | | |
| | | 7025 | 1 | 1 | | F | |
| | | 7028 | 2 | | X | F | |
| | | 7029 | | 1 | | | |
| | | 7040 | 1 | | | 15.3 | |
| | | 7045 | 2 | | | 15.5 | |

TABLE 1.c

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7048 | 2 | | | B | |
| | | 7049 | 3 | | | F | |
| | | 7050 | 2 | | | F | |
| | | 7061 | 1 | | | B | |
| | | 7063 | 1 | | | B | |
| | | 7068 | 1 | | | B | |
| | | 7069 | 1 | | | F | |
| | | 7073 | 1 | | | B | |
| | | 7074 | 1 | | X | F | |
| | | 7075 | 2 | | | B | |
| | | 7077 | 1 | | | F | |
| | | 7078 | 1 | | | B | |
| | | 7082 | 1 | 1 | | B | |
| | | 7083 | 2 | | | F | |
| | | 7089 | | 2 | | | |
| 83503 | Skynet A | 6304 | | 1 | | | |
| | | 6328 | | 2 | | | |
| | | 6329 | | 1 | X | | |
| | | 6330 | | 1 | X | | |
| | | 6337 | 1 | | | B | |
| | | 6338 | 1 | | | B | |
| | | 6339 | | 2 | | | |
| | | 6342 | | 1 | | | |
| | | 6346 | | 1 | | | |
| | | 6356 | | 3 | X | | |
| | | 6357 | | 3 | X | | |
| | | 6358 | | 1 | X | | |
| | | 6364 | | 4 | X | | |
| | | 7025 | | 1 | | | |
| | | 7048 | 2 | | | B | |

TABLE 1.d

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7049 | 2 | | | F | |
| | | 7050 | 2 | | | B | |
| | | 7063 | | 1 | | | |
| | | 7074 | | 1 | | | |
| | | 7077 | | 1 | | | |
| | | 7078 | | 1 | | | |
| | | 7079 | | 1 | | | |
| 83505 | SMS-3 | 6272 | 2 | | | B | |
| | | 6273 | 2 | | | B | |
| | | 6275 | 2 | | | B | |
| | | 6279 | 1 | | | B | |
| | | 6280 | 8 | | | B | |
| | | 6281 | 3 | | | B | |
| | | 6283 | 4 | | | B | |
| | | 6294 | 1 | | | B | |
| | | 6316 | 1 | | | B | |
| | | 6317 | | 1 | | | |
| | | 6346 | 3 | | | F | |
| | | 6349 | 1 | 2 | | B | |
| | | 6251 | 1 | | | B | |
| | | 6364 | | 1 | X | | |
| | | 7004 | | 3 | | | |
| | | 7007 | | 2 | X | | |
| | | 7012 | 1 | | | B | |
| | | 7013 | 2 | | | B | |
| | | 7014 | 1 | | | B | |
| | | 7019 | 8 | 1 | | B | |
| | | 7028 | 1 | | | B | |
| | | 7029 | | 2 | | | |
| | | 7035 | | 1 | | | |

TABLE 1.e

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7048 | 1 | | | B | |
| | | 7049 | 2 | | | F | |
| | | 7063 | 4 | | | B | |
| | | 7064 | 4 | | | B | |
| | | 7065 | 2 | | | B | |
| | | 7066 | 3 | | | B | |
| | | 7067 | 3 | | | B | |
| | | 7068 | 3 | | | B | |
| | | 7071 | 2 | | | B | |
| | | 7073 | 1 | | | B | |
| | | 7078 | 1 | | | B | |
| | | 7089 | 1 | | | B | |
| 83507 | IS II F-3 | 6279 | | 1 | | | |
| | | 6287 | | 1 | | | |
| | | 6304 | | 1 | | | |
| | | 6314 | | 1 | | | |
| | | 6317 | 1 | | | B | |
| | | 6330 | | 3 | X | | |
| | | 6339 | | 1 | | | |
| | | 6356 | | 2 | X | | |
| | | 6358 | | 2 | X | | |
| | | 7012 | 1 | | | B | |
| | | 7019 | | 2 | | | |
| | | 7028 | | 1 | | | |
| | | 7045 | 1 | | | 16.3 | |
| | | 7048 | 1 | | | B | |
| | | 7049 | 3 | | | B | |
| | | 7050 | 2 | | | F | |
| | | 7062 | | 1 | | | |
| | | 7067 | | 1 | | | |
| | | 7069 | 1 | | | F | |

TABLE 1.f

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7071 | 1 | | | B | |
| | | 7074 | 2 | | | B | |
| | | 7075 | 1 | | | B | |
| | | 7077 | 1 | | | B | |
| | | 7082 | 1 | | | B | |
| | | 7083 | 2 | | | B | |
| | | 7089 | 1 | | | B | |
| 83509 | Westar 1 | 6281 | | 1 | | | |
| | | 6364 | | 1 | X | | |
| | | 7011 | 1 | | | B | |
| | | 7012 | 1 | | | B | |
| | | 7013 | 1 | 1 | | B | |
| | | 7019 | | 1 | | | |
| | | 7020 | 2 | | | B | |
| | | 7028 | 1 | | | B | |
| | | 7035 | 1 | | | B | |
| | | 7048 | 1 | | | B | |
| | | 7049 | 1 | | | B | |
| | | 7063 | 3 | | | B | |
| | | 7064 | 1 | | | B | |
| | | 7065 | 3 | | | B | |
| | | 7066 | 3 | | | B | |
| | | 7067 | 2 | | | B | |
| | | 7068 | 1 | | | B | |
| | | 7075 | 1 | | | B | |
| | | 7083 | 1 | | | B | |
| | | 7089 | 1 | 1 | | B | |
| 83512 | IS I F-1 | 6287 | | 1 | | | |
| | | 6294 | | 1 | | | |
| | | 6304 | | 1 | | | |

TABLE 1.g

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 6363 | 2 | 2 | X | 17.9 | |
| | | 6364 | 1 | 2 | X | 17.0 | |
| | | 7028 | | 1 | | | |
| | | 7045 | 2 | | X | 15.2,16.9 | |
| | | 7048 | | 3 | | | |
| | | 7049 | | 2 | | | |
| | | 7050 | | 2 | | | |
| | | 7063 | | 1 | | | |
| | | 7071 | | 1 | | | |
| | | 7073 | 1 | | | B | |
| | | 7074 | | 2 | | | |
| | | 7078 | | 1 | | | |
| | | 7082 | | 1 | | | |
| | | 7083 | | 1 | | | |
| | | 7089 | | 2 | | | |
| 83513 | IS III F-2 | | | | | | |
| | | 6272 | 1 | | | B | |
| | | 6273 | 2 | 2 | | B | |
| | | 6274 | 4 | 2 | | B | |
| | | 6275 | 1 | | | B | |
| | | 6279 | 1 | | | B | |
| | | 6280 | 8 | | | B | |
| | | 6281 | 2 | | | B | |
| | | 6282 | 2 | 2 | | B | |
| | | 6283 | 3 | 2 | | B | |
| | | 6287 | 1 | | | B | |
| | | 6294 | | 1 | | | |
| | | 6295 | 1 | | | B | |
| | | 6304 | | 1 | | | |
| | | 6307 | | 2 | | | |
| | | 6314 | | 1 | | | |
| | | 6363 | | 3 | X | | |

TABLE 1.h

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7012 | | 1 | | | |
| | | 7014 | 1 | | | F | |
| | | 7019 | | 2 | | | |
| | | 7045 | 1 | | | 15.9 | |
| | | 7048 | 1 | | | B | |
| | | 7049 | 1 | | | B | |
| | | 7050 | 2 | | | F | |
| | | 7067 | 2 | | | B | |
| | | 7063 | 5 | 1 | | B | |
| | | 7064 | 2 | | | B | |
| | | 7065 | 2 | | | B | |
| | | 7066 | 2 | | | B | |
| | | 7067 | 1 | | | B | |
| | | 7068 | 1 | | | B | |
| | | 7069 | 1 | | | F | |
| | | 7073 | 2 | | | F | |
| | | 7074 | 1 | | | B | |
| | | 7075 | 1 | | | B | |
| | | 7077 | 1 | | | B | |
| | | 7078 | 1 | | | B | |
| | | 7082 | 1 | | | B | |
| | | 7083 | 2 | | | F | |
| | | 7089 | 1 | | | F | |
| 83523 | ATS-5 | 6272 | 2 | | | B | |
| | | 6263 | 4 | | | B | |
| | | 7274 | 4 | 1 | | B | |
| | | 6275 | 3 | | | B | |
| | | 6279 | 2 | | | B | |
| | | 6280 | 1 | | | B | |
| | | 6294 | 1 | | | B | |
| | | 6329 | 1 | | | B | |

TABLE 1.i

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 6351 | 1 | | | B | |
| | | 7007 | 2 | | X | 14.8 | |
| | | 7011 | 1 | 1 | | B | |
| | | 7012 | 1 | | | B | |
| | | 7013 | 2 | | | B | |
| | | 7028 | | 1 | | | |
| | | 7032 | | 1 | | | |
| | | 7048 | 1 | | | B | |
| | | 7049 | | 1 | | | |
| | | 7050 | | 1 | | | |
| | | 7063 | 4 | | | B | |
| | | 7065 | 3 | | | B | |
| | | 7066 | 3 | | | B | |
| | | 7067 | 1 | 1 | | B | |
| | | 7068 | 2 | | | B | |
| | | 7071 | 1 | | | B | |
| | | 7073 | 1 | | | B | |
| | | 7089 | 2 | 1 | | B | |
| 83530 | OV2-5 | 6294 | 1 | | | B | |
| | | 6295 | 1 | | | Flash,11;Diffuse,16 | |
| | | 6304 | | 1 | | | |
| | | 6307 | 1 | 1 | | B | |
| | | 6308 | | 1 | | | |
| | | 6363 | | 1 | | | |
| | | 6364 | | 1 | | | |
| | | 7012 | | 1 | | | |
| | | 7075 | | 1 | | | |
| | | 7077 | | 1 | | | |
| | | 7089 | | 1 | | | |

TABLE 1.j

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| 83533 | ATS-3 | 6272 | 1 | | | B | |
| | | 6273 | 3 | | | B | |
| | | 6274 | 5 | | | B | |
| | | 6275 | 3 | | | B | |
| | | 6279 | 2 | | | B | |
| | | 6280 | 7 | | | B | |
| | | 6281 | 3 | | | B | |
| | | 6282 | 3 | 2 | | B | |
| | | 6283 | 4 | | | F | |
| | | 6294 | | 1 | | | |
| | | 6304 | | 1 | | | |
| | | 6307 | | 1 | | | |
| | | 6308 | | 1 | | | |
| | | 6314 | | 1 | | | |
| | | 6346 | 1 | | | | |
| | | 6363 | 1 | | | B | |
| | | 7012 | 1 | | | B | |
| | | 7013 | 1 | 2 | | B | |
| | | 7019 | 6 | | | B | |
| | | 7028 | 2 | | | B | |
| | | 7035 | | 1 | | | |
| | | 7049 | 1 | | | B | |
| | | 7062 | 2 | | | B | |
| | | 7063 | 4 | | | B | |
| | | 7064 | 1 | | | B | |
| | | 7065 | 3 | | | B | |
| | | 7066 | 3 | | | B | |
| | | 7068 | 1 | | | B | |
| | | 7089 | | 2 | | | |

TABLE 1.k

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| 83534 | IS III F-6 | 6272 | | 1 | | | |
| | | 6273 | 1 | 1 | | B | |
| | | 6274 | | 4 | | | |
| | | 6275 | | 2 | | | |
| | | 6279 | | 1 | | | |
| | | 6294 | | 1 | | | |
| | | 6304 | | 1 | | | |
| | | 6307 | | 1 | | | |
| | | 6308 | | 1 | | | |
| | | 7049 | 2 | | | F | |
| | | 7063 | 2 | | | B | |
| | | 7064 | 1 | | | B | |
| | | 7065 | 4 | | | F | |
| | | 7066 | 2 | | | B | |
| | | 7070 | 1 | | | F | |
| | | 7077 | 1 | | | B | |
| | | 7089 | | 1 | | | |
| 83535 | ATS-1 | 6272 | 1 | | | B | |
| | | 6273 | 2 | 1 | | B | |
| | | 6274 | 3 | 1 | | B | |
| | | 6279 | 2 | | | B | |
| | | 6280 | 9 | | | B | |
| | | 6281 | 5 | | | F | |
| | | 6282 | 4 | | | B | |
| | | 6283 | 5 | | | B | |
| | | 6294 | 1 | | | B | |
| | | 6329 | 1 | | | B | |
| | | 7050 | | 1 | | | |
| | | 7063 | 2 | | | B | |
| | | 7065 | | 3 | | | |

TABLE 1.1

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO. OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7066 | | 1 | | | |
| | | 7069 | 1 | | | B | |
| | | 7070 | 3 | | | B | |
| | | 7071 | 1 | | | B | |
| | | 7074 | 1 | | | B | |
| | | 7078 | 1 | | | B | |
| | | 7089 | | 1 | | | |
| 83546 | IDCSP-14 | 6279 | | 1 | | | |
| | | 6281 | 1 | 1 | | B | |
| | | 6282 | 4 | 4 | | 13.5-F | |
| | | 6283 | 2 | 9 | | 14-F | |
| | | 6294 | 1 | | | B | |
| | | 6295 | 1 | | X | 17.8 | |
| | | 7025 | | 1 | | | |
| | | 7077 | | 1 | | | |
| 83547 | IDCSP-13 | 6273 | | 1 | | | |
| | | 6274 | | 3 | | | |
| | | 6287 | | 1 | | | |
| | | 6288 | | 2 | | | |
| | | 6290 | 1 | | | 16 | |
| | | 6316 | | 1 | | | |
| | | 6330 | | 1 | X | | |
| | | 7068 | | 1 | | | |
| 83550 | IDCSP-10 | 6279 | | 1 | | | |
| | | 6290 | 2 | | | 17 | |
| | | 6316 | | 1 | | | |
| | | 6330 | | 1 | X | | |

TABLE 1.m

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| 83550 | IDCSP-10 | 7025 | | 2 | | | |
| | | 7049 | | 1 | | | |
| | | 7050 | | 1 | | | |
| | | 7063 | | 1 | | | |
| | | 7074 | | 1 | | | |
| | | 7075 | 1 | | | B | |
| | | 7077 | 2 | | X | 13.5,17.2 | |
| | | 7089 | | 1 | | | |
| 83551 | HATCH COVER | 7050 | 1 | | | F | |
| | | 7064 | 1 | | | B | |
| | | 7069 | 3 | | | F | |
| | | 7070 | 1 | | | F | |
| | | 7071 | 1 | | | B | |
| | | 7074 | 1 | | | F | |
| | | 7075 | 1 | | | B | |
| | | 7077 | 1 | | | B | |
| | | 7078 | 1 | | | B | |
| | | 7080 | | 1 | | | |
| | | 7089 | 1 | | | F | |
| 83558 | RCA-A | 6316 | 1 | | | B | |
| | | 6329 | 1 | | | B | |
| | | 6349 | 1 | | | B | |
| | | 6351 | | 1 | | | |
| | | 7012 | 1 | | | B | |
| | | 7014 | | 1 | | | |
| | | 7018 | | 1 | | | |
| | | 7019 | 1 | | | B | |
| | | 7020 | 5 | | | B | |
| | | 7027 | | 1 | | | |

TABLE 1.n

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7032 | 1 | | | B | |
| | | 7035 | 1 | | | B | |
| | | 7063 | | 1 | | | |
| | | 7064 | 1 | | | B | |
| | | 7065 | 1 | 1 | | F | |
| | | 7066 | 1 | | | B | |
| | | 7067 | 1 | | | B | |
| | | 7071 | 1 | | | B | |
| | | 7075 | 1 | | | B | |
| | | 7077 | 1 | | | B | |
| | | 7089 | 1 | | | B | |
| 83560 | SMS-2 | 6275 | 2 | | | B | |
| | | 6279 | 1 | | | B | |
| | | 6280 | 4 | | | B | |
| | | 6294 | 1 | | | B | |
| | | 6304 | | 1 | | | |
| | | 6307 | 1 | 1 | | B | |
| | | 6308 | 1 | | | B | |
| | | 6314 | | 1 | | | |
| | | 6315 | 1 | | | B | |
| | | 6316 | 1 | | | B | |
| | | 6325 | | 1 | | | |
| | | 6342 | | 1 | | | |
| | | 6343 | 1 | | | B | |
| | | 6363 | | 1 | | | |
| | | 7019 | 8 | | | B | |
| | | 7020 | 1 | | | B | |
| | | 7025 | 1 | | | B | |
| | | 7027 | 1 | | | B | |
| | | 7028 | 2 | | | B | |
| | | 7032 | | 1 | | | |

TABLE 1.o

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7035 | | 1 | | | |
| | | 7040 | 2 | | | 14.6,14.8 | |
| | | 7049 | 1 | | | B | |
| | | 7063 | 3 | | | B | |
| | | 7064 | 1 | | | B | |
| | | 7065 | 2 | | | B | |
| | | 7066 | 2 | | | B | |
| | | 7067 | 1 | | | B | |
| | | 7070 | | 1 | | | |
| | | 7074 | | 1 | | | |
| | | 7078 | 1 | | | B | |
| | | 7083 | | 1 | | | |
| | | 7089 | | 1 | | | |
| 83567 | SMS-1 | 6272 | 1 | 2 | | B | |
| | | 6273 | 3 | | | B | |
| | | 6275 | 1 | 1 | | B | |
| | | 6279 | 1 | | | B | |
| | | 6294 | 1 | | | B | |
| | | 6304 | 1 | | | B | |
| | | 6308 | 1 | | | B | |
| | | 6314 | 1 | | | B | |
| | | 6315 | 1 | | | B | |
| | | 6316 | 1 | | | B | |
| | | 6328 | 1 | | | B | |
| | | 6330 | 12 | | | B | |
| | | 6342 | | 1 | | | |
| | | 6343 | | 1 | | | |
| | | 6349 | 1 | | | B | |
| | | 7004 | 1 | | | B | |
| | | 7077 | 1 | | | B | |

TABLE 1.p

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7014 | | 1 | | | |
| | | 7019 | 16 | | | B | |
| | | 7020 | 1 | | | B | |
| | | 7025 | 1 | | | B | |
| | | 7032 | 1 | | | B | |
| | | 7035 | 1 | | | B | |
| | | 7039 | 2 | | | B | |
| | | 7040 | 1 | | | 14.1 | |
| | | 7049 | 1 | | | B | |
| | | 7063 | 5 | | | B | |
| | | 7064 | | 1 | | | |
| | | 7065 | 3 | | | B | |
| | | 7066 | 1 | 1 | | B | |
| | | 7073 | 1 | | | B | |
| | | 7074 | 1 | | X | F | |
| | | 7075 | 2 | | | F | |
| | | 7077 | 1 | | | F | |
| | | 7078 | 3 | | | B | |
| | | 7082 | | 1 | | | |
| | | 7089 | 1 | | | B | |
| 83568 | LES-6 | 6274 | | 2 | | | |
| | | 6279 | | 1 | | | |
| | | 6281 | 1 | | | B | |
| | | 6282 | 3 | | | B-F | |
| | | 6283 | 6 | 4 | | B | |
| | | 6290 | | 3 | | | |
| | | 7050 | 2 | 1 | | B | |
| | | 7063 | | 1 | | | |
| | | 7064 | 5 | | | B | |
| | | 7075 | 2 | | | B | |
| | | 7066 | 1 | | | B | |

TABLE 1.q

| SATELLITE | | UTD | NO. OF TIMES OBSERVED | NO.OF TIMES NOT FOUND | INTEGRATION USED | B, F or $m_v$ | |
|---|---|---|---|---|---|---|---|
| SOC NUMBER | COMMON NAME | | | | | | |
| | | 7069 | 1 | | | B | |
| | | 7070 | 1 | | | B | |
| | | 7074 | | 1 | | | |
| | | 7075 | 1 | | | B | |
| | | 7077 | 2 | | | B | |
| | | 7078 | 2 | | | B | |
| | | 7083 | 1 | | | F | |
| 83569 | WESTAR 2 | 6280 | | 7 | | | |
| | | 6281 | | 2 | | | |
| | | 6294 | | 1 | | | |
| | | 6307 | | 1 | | | |
| | | 6308 | 1 | | | B | |
| | | 6310 | | 2 | | | |
| | | 6315 | | 1 | | | |
| | | 6339 | | 1 | | | |
| | | 6343 | | 1 | | | |
| | | 6363 | | 1 | | | |
| | | 7012 | | 1 | | | |
| | | 7028 | 1 | | | B | |
| | | 7029 | | 1 | | | |
| | | 7032 | 1 | | | B | |
| | | 7035 | | 1 | | | |
| | | 7049 | 1 | | | B | |
| | | 7063 | 1 | | | B | |
| | | 7064 | 1 | | | B | |
| | | 7065 | 4 | | | B | |
| | | 7066 | 2 | | | B | |
| | | 7067 | 1 | | | B | |
| | | 7068 | | 1 | | | |

ETS-12(1a)

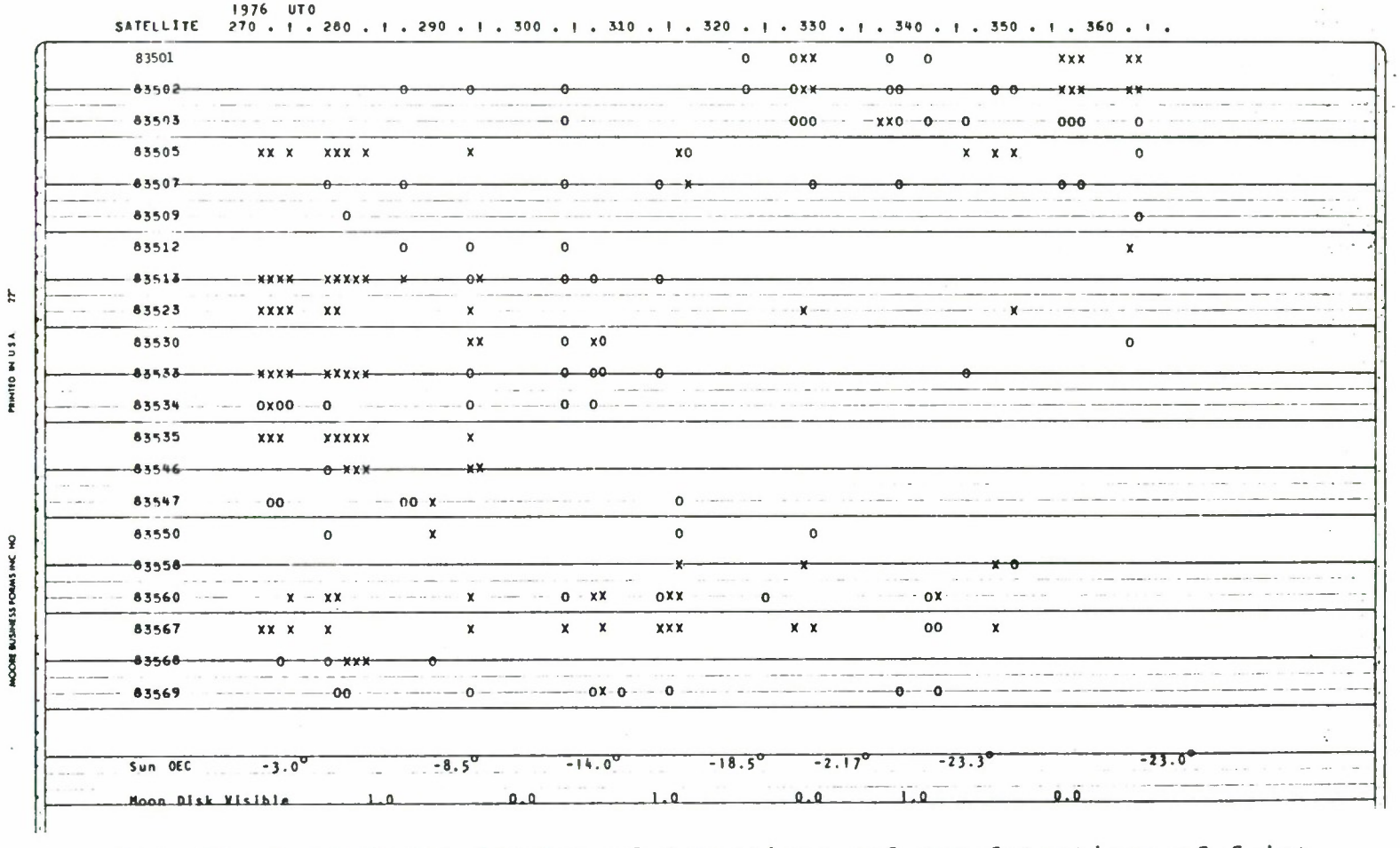


Fig. 1a A graphical display of detections and non-detections of faint synchronous satellites at the GEODSS ETS from October, 1976 to March 1977. Sun declination and lunar phase are included for comparison.

ETS-12(1b)

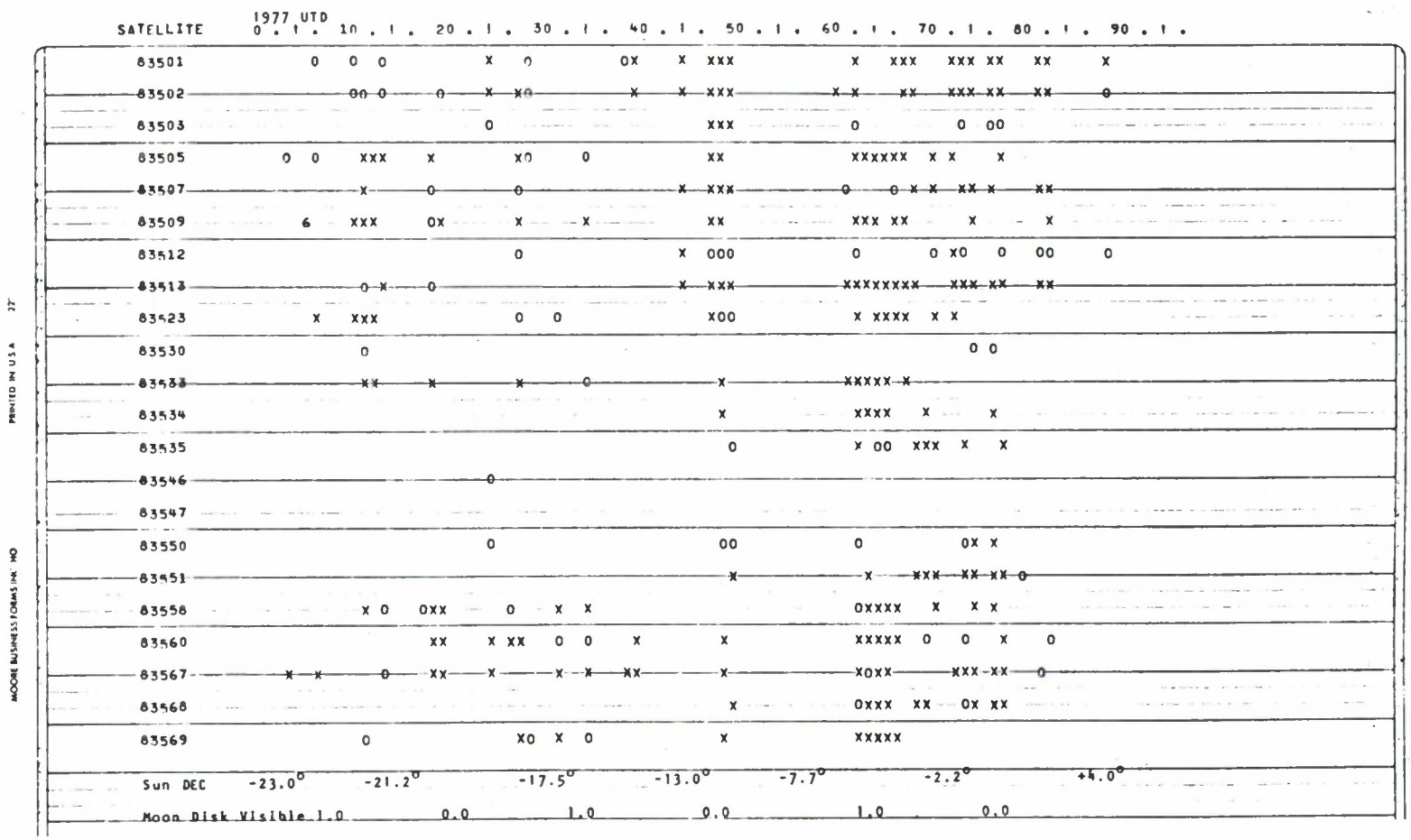


Fig. 1b A graphical display of detections and non-detections of faint synchronous satellites at the GEODSS ETS from October, 1976 to March 1977. Sun declination and lunar phase are included for comparison.

## REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ESD-TR-77-119
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE *(and Subtitle)*: Detections of Faint Geosynchronous Satellites at the GEODSS ETS from October 1976 to March 1977

5. TYPE OF REPORT & PERIOD COVERED: Project Report

6. PERFORMING ORG. REPORT NUMBER: Project Report ETS-12

7. AUTHOR*(s)*: Eugene W. Rork

8. CONTRACT OR GRANT NUMBER*(s)*: F19628-76-C-0002

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Lincoln Laboratory, M.I.T.
P.O. Box 73
Lexington, MA 02173

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
Program Element No. 63428F
Project No. 2128

11. CONTROLLING OFFICE NAME AND ADDRESS:
Air Force Systems Command, USAF
Andrews AFB
Washington, DC 20331

12. REPORT DATE: 10 June 1977

13. NUMBER OF PAGES: 34

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*:
Electronic Systems Division
Hanscom AFB
Bedford, MA 01731

15. SECURITY CLASS. *(of this report)*: Unclassified

15a. DECLASSIFICATION DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT *(of this Report)*:
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*:

18. SUPPLEMENTARY NOTES:
None

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*:
satellite detection
GEODSS
solar reflections
electro-optics

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*:

This report presents a record of faint geosynchronous satellites detected at the GEODSS ETS from October 1976 to March 1977. The satellites reported have at one time or another been difficult or impossible to detect electro-optically because solar reflections from them were faint.